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BEHAVIOR MODELING IN THE MULTI-FISHERY:

AN EVALUATION OF ALTERNATIVE METHODS

Walter Miklius
Department of Economics and Agricultural and Resource Economics
University of Hawaii
Honolulu, Hawaii 96822

Ping Sun Leung
Department of Agricultural and Resource Economics
University of Hawaii
Honolulu, Hawaii 96822

H-90-11C

ADMINISTRATIVE REPORT

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Walter Miklius
Department of Economics and Agricultural
and Resource Economics
University of Hawaii
Honolulu, Hawaii 96822

and

Ping Sun Leung
Department of Agricultural and Resource Economics
University of Hawaii
Honolulu, Hawaii 96822

NOT FOR PUBLICATION

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PREFACE

This report was prepared under contract as part of the Southwest Fisheries Center Honolulu Laboratory's economics research program. The purpose of the report was to provide a brief, informal, but candid evaluation of the linear programming methodology we have employed to model potential changes in Hawaii's large-scale commercial fisheries. In the process of working on this report, we were able to examine some of our linear programming results in detail. Although those results are not included herein, they provided useful insight into the linear programming approach to modeling allocation decisions. We are also encouraged with the potential applicability of the proposed methodology recommended by Walter Miklius and Ping Sun Leung, and we will be exploring its ramifications in the months to come.

Because this report was prepared by independent investigators, its statements, findings, conclusions and recommendations do not necessarily reflect the views of the National Marine Fisheries Service, NOAA.

Samuel G. Pooley
Industry Economist
Honolulu Laboratory
June 1990

1. Introduction

There is a two-fold motivation for this study. First, it appears that inspite of its importance very little effort has been devoted to modeling of fishermen's behavior. For example, Opaluch and Bockstael (1984) argue that it is essential for policy makers to be able to predict fishermen's responses to the economic and biological environment and to management policies. And that "...When behavioral response is incorrectly understood, regulatory policies can have unexpected and adverse effects,..." (p. 107). But, they further note that "...Unfortunately, little explicit modeling and estimation of behavior relationships has been accomplished to date..." (p. 107).

The second motivation is to broaden the scope of fishery studies. Most of the past studies have focused on single species fishery, i.e., they have been concerned with the effort level of fishermen within a single fishery.[1] However, the distribution of effort among fisheries can be changed by fishermen switching among fisheries.

Thus, the purpose of this report is to evaluate alternative methods for modeling behavior of fishermen in the multi-fishery. There are two basic methods available for this task: (1) linear programming and (2) random utility model. The application of linear programming for the purpose on hand is described in Section 2. An alternative to linear programming is the random utility model which is presented in Section 3. The random utility model can be estimated using two types of data: (1) data on past decisions, which hereafter is referred to as revealed preference (RP) data; (2) data generated in an experiment, which hereafter is referred to as the stated preference (SP) data. The estimation of the random utility model using RP and SP data is described in sections 4 and 5, respectively.

2. Application of the Linear Programming Model

A linear programming model of Hawaii commercial fisheries was developed by E.R.G. Pacific, Inc. (1986), and was subsequently modified and extended by the National

Marine Fisheries Service (Kasaoka, 1989 and 1990). The initial intent of the model was to analyze the potential impact of limited entry programs on various Hawaii fisheries and on the economic performance of various fishing fleets. The current version of the model (hereafter referred to as NMFS LP model) "enables the user to simulate different fishery scenarios that may reflect potential industry trends." For example, a manager may wish to examine the effects that changing fish prices, catch rates, annual yields or fishing costs might have on fishing strategies and profitability. The model allocates the limited fishing time of each vessel type among fishing areas and target species for each fishing season so as to maximize fleetwide profits.

The NMFS LP model covers the basic commercial fisheries in the major fishing areas in Hawaii. Five principal fleet categories are considered: small trailered/moored boats, medium-sized moored boats, medium-sized multipurpose boats, large multipurpose boats, and large catcher/processor boats. The species that vessels in each fleet can target are: bottomfish, pelagic management unit species (billfish, mahimahi, ono), lobster, aku and ahi. The four fishing areas which are delimited roughly along longitudinal lines are: main Hawaiian islands, lower northwestern Hawaiian islands (NWHI), upper NWHI, and a distant-water area. The fishing year is divided into three seasons: holiday (Dec-Jan), summer (May-Aug), and winter (Feb-Apr and Sept-Nov). It was originally envisioned that the model could depict the switching behavior of fishermen among bottomfish, longline, and lobster in the four fishing areas, and exit from the Hawaii fishery entirely. However, the results of a baseline run of the model do not even come close to the actual fisheries situation in Hawaii. In particular, this baseline solution shows that aku is never caught in any season from any area. This is very unrealistic. As Kasaoka (1990) puts it "It is important to reiterate that these (the baseline) results are hypothetical." The model developer (E.R.G. Pacific, Inc., 1986) provided the following explanations of the unrealistic solution: 1. Relationships in the model may not be linear; 2. Vessels within each fleet group may not be homogeneous with respect to their costs, catch rates and fishing

capacities; and 3. Incidental catches are not modelled. More importantly, as stated by Kasaoka (1990), "the linear program software employs the simplex methodology which does not allocate fishing effort evenly across the feasible range of time and space, but tends to lump it at the smallest possible number of profitable times and spaces (the corner points or vertices of this range)." In other words, the linear program "allocates" the limited resources (time and space) rather than "reproduces" the behavior of the fishermen.

As it stands, the NMFS LP model is a sector model with the overall objective of maximizing fleetwide profits. However, fishery decisions generally involve choices on at least two levels and fishery management in the U.S. seldom conforms to the NMFS LP objective (which is simply an idealized economic version of regulatory efficiency). At one level (the macro level) fishery policy makers are trying to allocate the limited natural resource (fish) subject to existing capital configurations. This is done given predictions on how fishermen will react to each possible allocation. At the other level, the micro level, fishermen have their own decision problem: how best to respond to each possible allocation, given their own objectives and limitations of action. Fishermen differ widely in their resources, wealth endowments, and economic opportunities. From an analytical point of view, this is the problem of predicting fishermen's reactions to fishery management decisions. In other words, the macro level problem is generally normative or prescriptive while the micro level problem is positive or descriptive. The micro level problem is almost always the more difficult from an analytical point of view. It is also most important for the following reason: until fishermen's behavior (responses) are better understood, the consequences of policy actions cannot be specified for the policy decision model.

The present LP formulation does not incorporate the micro level decision of the fishermen. This would be appropriate only if the policy makers could control directly the fishermen's production decisions. Then the problem collapses to the case of pure centralized planning. Obviously the centralized planning formulation is not very useful in reality. Hence the overall policy problem can better be described as a two-level decision

problem. In other words, the fishermen's decision (optimization) model will be nested under the overall policy decision (optimization) model. This type of model is not generally solvable directly but indirect methods have developed to solve the two-level problem approximately (Hazell and Norton, 1986).

This is the omission of the micro level decision of the fishermen that led to the unrealistic solutions of the NMFS LP model. Opaluch and Bockstael (1984) have noted the importance of accurately predicting the response of fishermen to public policy. They use a discrete choice model to predict fishermen's supply function and show that fishermen respond to economic incentives of expected returns and variability of returns, but only after these incentives surpass a substantial threshold. This is explained further in sections 3, 4 and 5.

3. Random Utility Model

Suppose that the individual decision maker is confronted with a choice among a set of alternatives, which, for example, might include various bundles of attributes applicable to achieving an objective. The choice is assumed to depend on the relative utilities of the various options. Typically, an additive utility function is specified:

$$U_{im} = \sum_{j} \beta_{ij} X_{ijm} \qquad (1)$$

where:

U_{im} is the modeled value for the utility perceived by individual i for alternative m; X_{ijm} is the value of the jth relevant attribute (explanatory variable) which is hypothesized to influence choice; β_{ijm} are parameters "known" by the individual decision maker, reflecting utility weights, but unknown to the observer, and to be in some way estimated.

The individual will choose that alternative from all those available which is perceived as having the highest utility. However, there will be influences on an individual's choice which cannot be readily measured or recognized. Thus, a stochastic

element, ε_{im}, is added to the deterministic expression of the equation (1) to represent the net effect of omitted factors, and to form "Random Utilities," RU_{im}, as:

$$RU_{im} = U_{im} + \varepsilon_{im} \qquad (2)$$

The probability that alternative 1 rather than alternative 2 will be chosen can be expressed as:

$$P_{i1} = \text{Prob}\,[(U_{i1} + \varepsilon_{i1}) > (U_{i2} + \varepsilon_{i2})] \qquad (3)$$

The assumptions made about the error term determine the form of the model. The assumption that errors are independently and identically distributed with a Weibull distribution yields the most commonly used form of random utility model, i.e., the logit model,

$$P_{i1} = \exp(U_{i1}) / \sum_{m} \exp(U_{im}) \qquad (4)$$

which is fully derived in McFadden (1974). Calibration will provide estimates of scale transformations of the marginal utilities, $ß_{ijm}$, of equation (1). The multinominal probit model can also be derived from equation (3) by assuming that the errors have a multivariate normal distribution (Hausman and Wise, 1978).

As it was pointed out above the model can be estimated using data on past decisions or can be estimated using data generated by an experiment. The estimation of the model using these two types of data is discussed in the next two sections, respectively.

4. Estimation of the Model Using RP Data

Opaluch and Bockstael (1984) provides an example of the study in which the model was estimated using the RP data. Their data consisted of a cross-sectional sample of 657 fisherman landing fish in New England ports and included all vessels reported in the National Marine Fisheries Service landings records except those less than 5 gross tons or

those which were on the fishing grounds fewer than 100 days each year. Each vessel participated in the fishery in 1975 and subsequently made a choice amongst fishery in 1976. A fishery alternative was defined as a group of species which could be harvested by a single gear type in a given geographic location. Depending on the fisherman's vessel and initial situation, the number of alternatives varied between nine and twelve.

In specifying the model, i.e. the probability of an individual fisherman choosing a particular alternative based on observable characteristics, Opaluch and Bockstael hypothesize that fishermen would not switch immediately to the most profitable fishery because of both monetary and nonmonetary costs of switching. The former include the costs of converting gear and changing ports. For the latter they include the costs of acquiring expertise in a different type of fishery or on different fishing grounds or the psychic costs of departing from family tradition or simply overcoming inertia. Thus, they include a dummy variable to account for all sources of resistance to switching.

They assume that the error term is distributed as Weibull random variable, thus, the result is logit model which is estimated using maximum likelihood methods. The empirical results suggest that while fishermen respond to economic incentives they exhibit a strong inclination toward remaining within the same fishery over time. The estimated model overall is significant at the extremely high level.

However, the main disadvantage of the estimation of RU model using RP data is that information on profitability of switching is not available at the time switching decision is made. Therefore, the decision has to be based on expected profitability which is not revealed by the past decision and may differ from ex post estimated profitability.

5. Estimation of the Model Using SP Data

In the previous section an illustration was provided of the estimation of the random utility model using historical data. As it was pointed out above the model could also be

estimated using data generated by an experiment. This method of generating data is known as the stated preference method.

The term "stated preference" refers to a family of techniques that are known under a wide variety of names. The best known are conjoint analysis, functional measurements, and trade-off analysis. They were originally developed in the fields of mathematical psychology and psychometrics in the late 1960s, were adopted to marketing problems in the early 1970s and have been used widely since the mid-1970s. In economics the only field in which SP methods have been widely adopted is transportation economics.[2]

The common characteristic of the SP methods is their reliance on data generated by experiments in which subjects are asked to state their choices among a number of realistic but hypothetical situation. In contrast, in the study discussed above the random utility model was estimated using information revealed by the past choices and for this reason we will refer to utilizing this type of data as the "revealed preference" or "RP" methods.

The economists typically prefer the RP methods because they are based on the observed behavior of the participants in the marketplace. However, there are numerous situations where limitations of the RP methods restrict their general suitability. First, revealed preference data may not be available. Second, there may be insufficient variation in the revealed preference data to examine all variables of interest. Third, there may be a strong intercorrelation among explanatory variables. Fourth, the RP methods are unsuitable for estimation of parameter values for conditions that did not exist in the past.

There are additional advantages of the SP methods. First the researcher has a much greater control on what is and what is not to be considered since he/she defines the conditions which are to be evaluated by the respondents. Second, they are more flexible, i.e., they are capable of dealing with a wide variety of variables. Third, they are cheaper to apply because each respondent provides multiple observations.

The main disadvantage of the SP methods is that people may not necessarily do what they say. While the SP methods provide an internal validity test, i.e., the responses

have to be transitive to be valid, there is no built-in test for external validity. That is, there is no assurance that parameter estimates obtained in the experimental setting would be equally valid in the real world setting. Actually, however, the problems of external validity may be as severe for RP methods. For example, there is no assurance that parameters estimated using historical data are still valid today or that parameter estimates obtained in one setting are transferable to another.

The "external" validity of the SP methods has been the objective of a large number of studies. These studies are evaluated in Levin et. al. (1983) and Louviere (1988). In general, where the comparison was possible the study using SP methods always outperformed the study using RP methods. Thus, Louviere concludes his review with the following statement: "...We therefore suggest that there is considerable evidence to support the conclusion that appropriately designed, implemented and analyzed conjoint studies can predict the real behavior or real individuals in real markets" (p. 114).

As we have pointed out above the SP methods do not break new ground as far as economic theory but are based on a well established random utility model. Furthermore, Hensher et. al. (1988) have shown that it is the indirect utility function that is being estimated, i.e., the measure of utility which internalizes the constraints arising from income and other sources.

In short, the SP methods in certain situations provide a viable alternative to RP methods. In others they provide the only available option.

6. Application of SP Methods to the Hawaii Fishery

This section provides an illustration of a possible application SP methods to modeling decisions of long-line fishery vessel owners to engage in lobster fishing during the off-season.

In Hawaii the off-season for long-line fishery starts at the beginning of May and lasts through October. During the off-season the vessels could be used in the lobster

fishery. However, they would need to be retrofitted which takes up about a month of time. The decision to retrofit, therefore, typically has to be made in April. Alternatively, they could be left idle or used in other fisheries not requiring retrofitting.

The first step in the design of an SP study is to develop a set of realistic decision making scenarios. This requires specification of the factors that decision makers typically take into account while making decisions and their possible levels. In the retrofitting decision it appears that the four following factors are being taken into account: (1) The current price of lobsters (in April); (2) The current catch of lobsters (in April); (3) The expected value of the catch of alternative fisheries which does not require retrofitting; (4) The seasonal taper in the value of lobster catch in the preceding season. Typically, the value of the lobster catch early in the season is relatively high but tapers off as the season progresses. The rapid decline to a relatively low level will tend to reduce expectations for the coming season and discourage retrofitting or vice versa.

Thus, we have to consider four variables (called "factors"). If we specify three levels each, we have 81 possible combinations. Most combinations, however, will be dominated by other combinations, where the dominance refers to a situation where one combination is equal or superior to another one, so that no tradeoffs are involved in selecting among alternatives. These combinations should be excluded. Thus, only 12 combinations will involve tradeoffs from the base line combination. These combinations are shown in Table 5.1 where 1 is assigned to the level of each factor most favorable to retrofitting and 3 to the least favorable. For example, in comparison to No. 1, which is the base line combination, No. 2 has more favorable level of factor 1 but a less favorable level of factor 2. Other combinations involve similar tradeoffs between levels of other factors.

Once the combinations of factors and levels are decided upon, the panel of respondents is selected from the population of vessel owner/operators. Each respondent is presented these combinations as representing hypothetical but realistic decision making scenarios one at the time and is asked if he/she would or would not retrofit his vessel for

lobster fishing. His/her decision is recorded as 1 if the decision is to retrofit or 0 otherwise and the next combination is presented with the same request.

For each response to the hypothetical scenario we have a discreet zero-one dependent variable and values of four independent variables. Thus, each respondent supplies 13 observations. The next task is to use the logit or probit model to estimate the choice function for the panel of respondents which shows the weights they attach to each of the four variables.

Economy theory provides no guidelines for the form of the choice of the functional form. Although it is common to assume a linear additive function this seems too restrictive. It may be preferable to estimate various forms and then select one that fits the best. The flexible forms, such as translog functions, have also been used in more recent studies. Once the choice model has been estimated potentially (depending on the variables included) all the behavior phenomena based on utility theory can be derived.

In the preceding example responses of the panel members had to be aggregated and one choice function estimated for the panel. However, the number of combinations could be increased by increasing the number of levels. This would increase the number of observations considered for each panel member which, in turn, may be sufficient to estimate a separate choice function for each individual panel member. In that case, supply curves can be estimated by varying one factor and holding others constant. This makes it rather simple to estimate the impact of change in any one independent variable on decision.

We believe that the SP methods provide an attractive alternative for modeling decisions in the fishing industry. While we used retrofitting decision as an example, the method could be applied to vessel homeporting, selection of fishing grounds and other decisions as well.

Footnotes

1. In Hawaii, the analysis of lobster fishing performance by Clarke and Pooley (1988) and the analysis of bottom fishing vessels by Pooley and Kawamoto (1990) serve as examples.

2. In fact, the leading journal in this field, *The Journal of Transport Economics and Policy*, has recently devoted an entire issue to the SP methods (Vol. 22, No. 1, January 1988).

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Table 5.1 Combinations of Factors and Levels Involving Tradeoffs

Comb. #	Factor 1†	Factor 2	Factor 3	Factor 4
1 (base line)	2††	2	2	2
2	1	3	2	2
3	1	2	3	2
4	1	2	2	3
5	3	1	2	2
6	3	2	1	2
7	3	2	2	1
8	2	1	2	3
9	2	2	1	3
10	2	3	2	1
11	2	2	3	1
12	2	1	3	2
13	2	3	1	2

† Factor (1) The current price of lobsters (in April).
(2) The current catch of lobsters (in April).
(3) The expected value of the catch of alternative fisheries which does not require retrofitting.
(4) The seasonal taper in the value of lobster catch in the preceding season.

†† Value 1 = More favorable to retrofit.
2 = "Neutral".
3 = Less favorable.